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Ecological social capital does not predict geographical variance in increases in depression following the 2008 financial crisis

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Research suggests that the financial crisis of 2008 and its aftermath were associated with an increase in mental health problems, but there has been little research into potential protective factors. Ecological social capital is a plausible candidate given evidence of its protective status following natural disasters. Pre-crisis area-level estimates of generalized trust and sense of belonging were computed from the 2004 to 2006 waves of the Living in Wales survey ($N = 43,473$) for 413 neighbourhoods in Wales, using multilevel regression with post-stratification, a technique for disaggregating survey data into small area estimates. Area estimates and the planned analysis were preregistered using Open Science Framework. Data ($N = 180,462$) from the Welsh Health Survey (2003–2015) were then used to model whether social capital was protective against depression in general and whether it moderated the increase in depression prevalence, associated with the financial crisis. Depression rates increased post-crisis (odds ratio [OR] = 1.271), and trust was a protective factor against depression (OR = 0.775). The hypothesized interaction, however, was not significant (OR = 1.033), nor was sense of belonging (OR = 0.934) or its interaction with the crisis (OR = 1.024). Although ecological generalized trust appears to be a protective factor against depression, it did not buffer against the mental health impact of the financial crisis.

Along with its obvious economic consequences, the global financial crisis of 2008 is thought to have been a public mental health crisis. Studies from several countries suggest that suicide rates (Barr, Taylor-Robinson, Scott-Samuel, McKee, & Stuckler, 2012; Economou, Madianos, Theleritis, Peppou, & Stefanis, 2011) and reported mental health problems (Barr, Kinderman, & Whitehead, 2015; Bartoll, Palència, Malmusi, Suhrcke, & Borrell, 2014; Wang *et al.*, 2010) increased during the crisis and in its aftermath.

The mental health consequences appear not to have fallen evenly across the populations studied. Increases in suicide in England were greatest in local authority areas where increases in unemployment were greatest (Barr *et al.*, 2012), while the increases in mental health problems increased existing health gradients along educational and social class lines in some studies (Barr *et al.*, 2015; Bartoll *et al.*, 2014), but flattened educational health gradients in others (Wang *et al.*, 2010). Older Americans who lost significant

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retirement savings in the immediate crisis also reported greater antidepressant use and poorer mental health (McInerney, Mellor, & Nicholas 2013).

These studies used moderation analyses to support the argument that the increases in mental health problems were indeed related to the crisis, rather than speaking to the question of whether particular groups were more or less vulnerable to the putative mental health consequences of the crisis. The latter question, however, has obvious implications for subsequent crises, not least in terms of whether there are ways in which communities can be helped to become more resilient.

One potential protective factor comes from the literature on resilience to natural disasters. Social capital, conceptualized here in the communitarian sense of Putnam (2000), is an influential construct across the social sciences, defined as the social resources available to members of a group, such as trust, norms, and sanctions, that stem from their social network. This includes beliefs (cognitive social capital) as well as institutions and practices (structural social capital). Cognitive social capital can further be divided into individual-level social capital and ecological social capital, which will be focused on in the present paper. Ecological social capital represents the aggregated cognitive social capital of people within a geographical area, and is important because many of the potential benefits of social capital rely on the collective action of communities, rather than beliefs on an individual level.

Social capital is a well-established protective factor against a range of poor physical (Kawachi, 1999) and mental health (Ehsan & De Silva, 2015) outcomes. As well as its broader health benefits, it has come to the attention of researchers into community resilience in the wake of natural disasters (Aldrich & Meyer, 2015) where ecological social capital appears to be a protective factor. The most famous example of this was Klinenberg's seminal work on the 1995 Chicago heatwave (Klinenberg, 1999, 2003), which identified the social capital of the city's Latino population as a key protective factor for this group.

This paper is not the first to link social capital to resilience in the face of the financial crisis – Economou *et al.* (2014) looked at interpersonal and institutional trust as protective factors against depression in the financial crisis in Greece, finding that trust was protective in survey respondents who were not financially distressed, but not protective in those who were. Lindström and Giordano (2016) used data from the British Household Panel Survey to examine how generalized trust changed from 2007 to 2008, and whether it remained protective against poor mental health in this period, finding that trust declined between 2007 and 2008, but remained protective. Frank, Davis, and Elgar (2014) surveyed economically distressed towns in Canada and found that a social capital measure moderated the relationship between financial strain and depressive symptoms.

None of these studies, however, looked at whether pre-crisis *ecological* social capital was a predictor of the magnitude of the increase in mental health problems following the crisis, instead looking at individual-level social capital and its contemporaneous association with mental health. Given the evidence that financial crises can reduce trust (Lindström & Giordano, 2016), the question of whether pre-crisis social capital is a protective factor is an important question. Furthermore, the question of whether ecological social capital is a general protective factor against mental health problems or whether it appears to reduce the impact of the crisis (i.e., moderates the effect) is also important.

The present study uses a repeated cross-sectional survey series, the Welsh Health Survey, to quantify the increase in reported treatment for depression following the financial crisis and how it varied geographically. A second survey, Living in Wales, was

used to produce small area estimates of pre-crisis ecological cognitive social capital, using multilevel regression with post-stratification (MRP), a modelling approach for disaggregating survey responses into small area estimates (Gelman, Little, & Witter, 1997; Park, Gelman, & Bafumi, 2004), which has previously been used to estimate social capital measures across Wales to predict contemporaneous psychiatric admission rates (Saville, 2019).

It is hypothesized that ecological social capital will be a protective factor against depression and that it will moderate the increase in depression following the crisis, such that residents of high ecological social capital areas are buffered against the mental health consequences of the crisis.

Methods

The study received ethical approval from Bangor University School of Psychology Ethics Committee, and access to survey respondents' middle super output areas (MSOA) of residence was granted by the Welsh Government's Survey Team.

Preregistration details

Multilevel regression with post-stratification estimates of two measures of ecological cognitive social capital, generalized trust and sense of belonging, were finalized and uploaded to the Open Science Framework prior to accessing MSOA data for the Welsh Health Survey to ensure transparency regarding *p*-hacking. Prior to preregistration, I had access to the Welsh Health Survey data, except data on respondents' MSOA of residence. The analysis plan, including finalizing the MRP modelling, was preregistered prior to accessing the MSOA data for the Welsh Health Survey. Thus, the analyses of the association between ecological social capital and depression rates and the interaction between ecological social capital and time point (pre- vs. post-crisis/austerity) were preregistered blind, but the analysis of the time point was not, as these data were available prior to preregistration. The preregistration can be found here: <https://osf.io/7ebd8>. Departures from this protocol are detailed at the end of the Results section.

MRP estimates

Multilevel regression with post-stratification was used to compute estimates of ecological social capital for each of the 413 MSOAs (a unit of UK Census geography) covering Wales from the 2001 census. MRP-derived estimates of ecological social capital have been previously shown to predict psychiatric admission rates in Wales, using a very similar method (Saville, 2019). The data used were the pooled 2004, 2005, and 2006 waves of the Living in Wales survey, a now-discontinued survey series commissioned by the Welsh Government (Welsh Assembly Government & Statistical Directorate, 2010), with a pooled sample size of 43,473. Households were randomly sampled, stratified by local authority, with response rates of 61.1%, 59.4%, and 61.0% for the 2004, 2005, and 2006 waves respectively. Data were available for respondents from all MSOAs, with a range of 26–328 (median = 96) per MSOA. It is worth underlining the size of this sample – according to the 2001 UK Census, it represents almost 1.9% of the population of Wales aged over 16 (Office for National Statistics, 2011).

Multilevel regression with post-stratification estimates were computed for two separate constructs: generalized trust and sense of belonging. Generalized trust was measured using the item 'Would you say that you trust...?' with the following response options: 'most of the people in your neighbourhood', 'many of the people in your neighbourhood', 'a few of the people in your neighbourhood', and 'or that you do not trust people in your neighbourhood'. Responses were dichotomized with the first two options being recoded to 1 and the latter two to 0. Sense of belonging was measured using the item 'I feel like I belong to this neighbourhood' with the following response options: 'strongly agree', 'tend to agree', 'neither agree nor disagree', 'tend to disagree', 'strongly disagree', and 'don't know'. Responses were dichotomized with the first two options being recoded to 1 and the remaining options to 0. These scales were dichotomized as Likert-scale responses violate assumptions of interval-level data, and can also cause convergence problems with this type of modelling.

Age was recoded to bands corresponding with table CS133 'Sex and age by knowledge of Welsh' from the 2001 UK Census: 16–19, 20–24, 25–39, 40–49, 50–59, 60–64, 65–74, and 75+. Those responding 'don't know' to the Living in Wales question on whether they could speak Welsh ($N = 51$) were recoded to 'no', to correspond with the possible census responses.

Middle super output areas-level data on population density, the proportion of residents aged 16+ with no formal qualifications, the proportion of residents aged 18+ who were married, and the proportion of residents providing unpaid care were all taken from the 2001 UK Census.

The lme4 package (Bates, Maechler, Bolker, & Walker, 2015) for R (R Core Team, 2019) was used to fit separate binomial generalized linear mixed-effects models to the data for generalized trust and sense of belonging. These two models had the same random-effects structure: random intercepts of sex, age band, MSOA, and local authority (22 county council areas); and random slopes of Welsh-speaking for each MSOA and local authority. The random slopes were included because being a Welsh speaker was expected to vary in its demographic correlates and cultural significance across Wales (Balsom, 1985; Evans, 2019). For trust, fixed effects of population density, proportion of residents with no formal qualifications, and proportion of married residents were used as area-level predictors; for belonging, fixed effects of density, proportion of unpaid carers, and proportion of married residents were used.

The nomisr package (Odell, 2018) for R was used to download 2001 census table CS133 and the proportion of the population in each age \times sex \times Welsh-speaking stratum was computed for each MSOA. The appropriate level of each random effect was then summed for each age \times sex \times Welsh-speaking \times MSOA cell and the cells constituting each MSOA were summed, weighted by their share of its population. Each fixed effect was multiplied by the appropriate value for each MSOA and added, along with the intercept of the model, to each MSOA's value, which was inverse logit-transformed, giving an estimated percentage of each MSOA's population that gave a positive answer (after dichotomization) to the trust/belonging question.

Trust

In the individual model, lower population density ($z = -5.520$, $p < .0001$) and proportion of residents without formal qualifications ($z = -10.673$, $p < .0001$); and higher proportions of married residents ($z = 7.110$, $p < .0001$) were associated with greater rates of trust. Older residents were more trusting ($\sigma = .1467$) and women were

very slightly less trusting than men ($\sigma = .0018$). Substantial variability existed between MSOAs ($\sigma = .2471$) and local authorities ($\sigma = .0364$) after accounting for other factors and, as expected, speaking Welsh varied in its predictive value across different MSOAs ($\sigma = .1107$) and local authorities ($\sigma = .0298$). After computing the MSOA-level estimates, trust varied from 17.26% to 93.64%, with a median of 74.18%

Belonging

In the individual model, lower population density ($z = -3.585$, $p < .0001$); and higher proportion of unpaid carers ($z = 2.056$, $p < .0001$) and married residents ($z = 4.530$, $p < .0001$) were associated with greater rates of belonging. Older residents felt greater belonging than younger residents ($\sigma = .2251$) and women felt slightly greater belonging than men ($\sigma = .0013$). Substantial variability existed between MSOAs ($\sigma = .3879$) and local authorities ($\sigma = .1074$) after accounting for other factors and, as expected, speaking Welsh varied in its predictive value across different MSOAs ($\sigma = .2209$) and local authorities ($\sigma = .1704$). After computing the MSOA-level estimates, belonging varied from 36.11% to 93.93%, with a median of 80.52%

Maps of MRP estimates of trust and belonging can be seen in Figure 1. Trust is generally high (c. 80%) across rural Wales with particular pockets of low trust (40–60%) in the south Wales valleys, parts of the north coast, and parts of the larger cities in the south. Belonging is more evenly distributed and generally high, but is low in pockets of the larger cities and towns. The estimates can be downloaded at <https://osf.io/7ebd8>.

The geography of the ecological social capital estimates, especially trust, appeared similar to the geography of poverty in Wales. To assess the extent of the correlation, indicator data for the Welsh Index of Multiple Deprivation (the Welsh Government's official poverty measure) on areas rates of low pay were downloaded for 2005. These data were given by lower super output area, a more fine-grained geography than MSOA, so the mean low pay rate of all LSOAs in each MSOA was taken to represent the MSOA. A Spearman correlation was computed between low pay rates and the MRP estimates. Trust and rates of low pay were correlated, $\rho = -.70$, while belonging and rates of low pay were

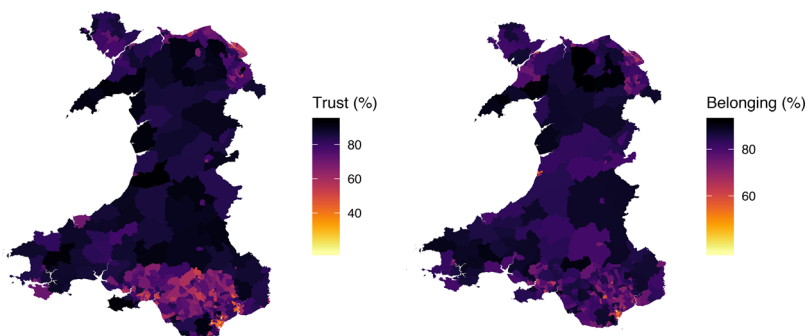


Figure 1. Multilevel regression with post-stratification estimates of generalized trust and sense of belonging for all Welsh middle super output areas. Two choropleth maps of Wales, one showing generalized trust and the other showing belonging. Both show high ecological social capital in most rural areas but pockets of low social capital in Cardiff, Swansea, Wrexham, and Newport and across the south Wales valleys. For the south Wales valleys, the pattern is much stronger for trust than belonging.

correlated, $\rho = -.30$, so areas with greater numbers of low paid people had lower ecological social capital estimates.

Welsh Health Survey analysis

Data for all 12 waves (2003/4–2015) of the Welsh Health Survey (Beaufort Research Limited *et al.*, 2011a, 2011b; NatCen Social Research, 2011a, 2011b, 2011c, 2011d, 2013, 2014a, 2014b, 2015a, 2015b, 2016), a cross-sectional survey on health conditions, health behaviour, and well-being run by the Welsh Government, were used to test whether increases in depression rates during the 2008 financial crisis and its aftermath were moderated by ecological social capital. Data on the MSOA of residence for each respondent were requested from the Welsh Government after preregistration of the analysis protocol and code. These were combined with data on age band (16–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, and 75+), sex, household ID (multiple occupants of each household filled in the survey), whether the respondent reported being treated for depression, and the year of the survey the respondent was sampled in. The overall sample size was 180,462, with a minimum of 12,689 and a maximum of 15,699 respondents a year.

Binomial generalized linear mixed-effects models were fitted to the data using the *glmmTMB* package (Brooks *et al.*, 2017) for R,¹ predicting whether participants reported being treated for depression. Fixed effects of ecological social capital (*z*-scored; trust or belonging, with separate models being fitted for each), time point (pre- vs. post-financial crisis: 2004–2007 waves vs. 2008–2015 waves; pre- vs. post-austerity onset: 2004–2009 vs. 2010–2015. Separate models fitted for financial crisis and austerity), the interaction of ecological social capital and time point, age band, and sex. Random intercepts were included for household nested within MSOA. The analysis was weighted by sampling probability on the individual level.

Four separate models were fitted: the combinations of the two ecological social capital estimates (trust or belonging) and the two time point definitions (financial crisis or austerity). As these pairs of predictors were correlated, a 5% alpha was corrected by the effective number of independent tests run, as indicated by the M_{eff} method (Derringer, 2018), specifically 2.719021, for an alpha of .01838897.

Results

Figure 2 shows the proportion of respondents who report treatment for depression by year. A modest increase is seen after the financial crisis and a larger one is evident in 2010 when fiscal austerity began. Figure 3 shows reported treatment for depression rates broken down by ecological social capital quartiles (separately for the two social capital measures). An apparent gradient in depression rate is clear in both, but appears steeper for trust than belonging. Figure 4 shows treatment for depression rates broken down by year and social capital quartile. The results of all models can be found in Table 1.

¹ The original preregistered plan was to use the *lme4* package, and to model household and MSOA as ‘crossed’ random effects, with a random slope of crisis/austerity in each MSOA. Due to convergence issues, the model was tweaked slightly. Results were qualitatively similar when using the original analysis plan without integrating out the random effects before estimating the fixed effects (i.e., the number of adaptive Gauss–Hermite quadrature points set to zero).

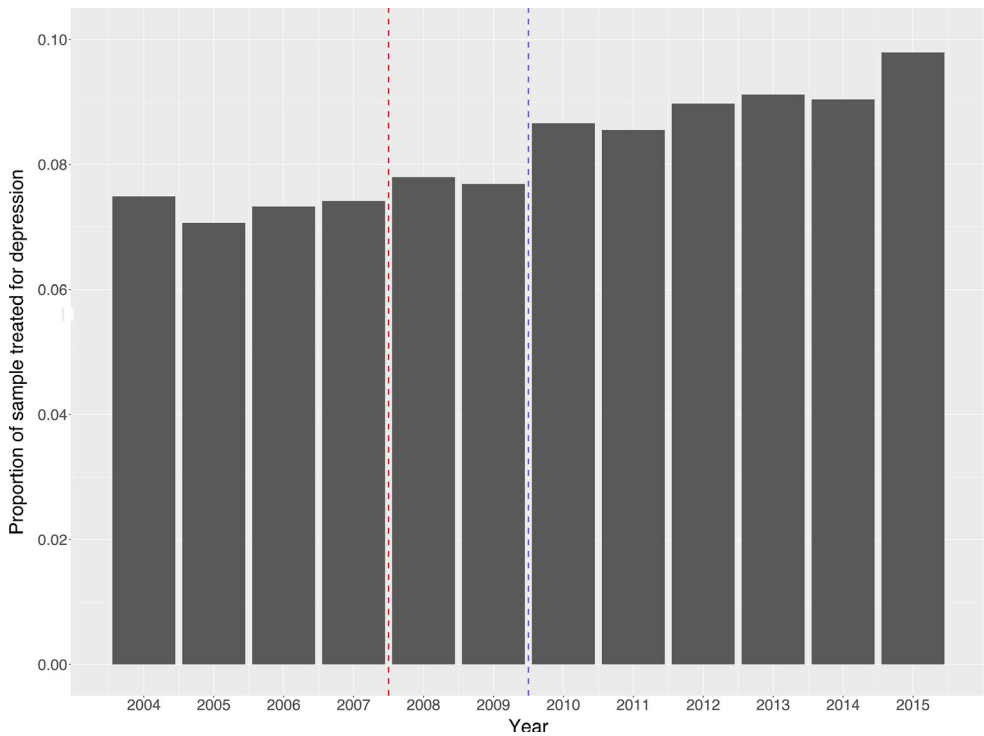


Figure 2. Reported treatment for depression rates by year. Red line indicates division of data into pre- and post-financial crisis epochs, and blue line indicates division of data into pre- and post-austerity epochs. A series of bars for depression rates in each year, with dashed lines separating 2008 and 2009, and 2009 and 2009 and 2010, to represent the two time point schemes analysed. There is a general upward trend in rates, from ~7.5% to approaching 10%, but there is a striking jump between 2009 and 2010, coinciding with the onset of austerity.

Trust

For the model using the financial crisis as the time point, depression was higher post-crisis (odds ratio [OR] = 1.271 [CI_{95%}: 1.123–1.438], $p = .0001$) and lower in MSOAs with greater trust (OR = 0.775 [CI_{95%}: 0.706–0.852], $p < .0001$). The hypothesized interaction, however, was not significant (OR = 1.033 [CI_{95%}: 0.922–1.157], $p = .5735$).

For the model using austerity as the time point, depression was higher during austerity (OR = 1.28 [CI_{95%}: 1.142–1.435], $p < .0001$) and lower in MSOAs with greater trust (OR = 0.789 [CI_{95%}: 0.731–0.853], $p < .0001$). The hypothesized interaction, again, was not significant (OR = 1.008 [CI_{95%}: 0.908–1.20], $p = .8790$).

Belonging

For the model using the financial crisis as the time point, depression was higher post-crisis (OR = 1.265 [CI_{95%}: 1.120–1.490], $p = .0002$), but belonging was not protective (OR = 0.922 [CI_{95%}: 0.838–1.016], $p = .1010$). The hypothesized interaction was also not significant (OR = 1.024 [CI_{95%}: 0.913–1.150], $p = .6780$).

For the model using the austerity as the time point, depression was higher during austerity (OR = 1.278 [CI_{95%}: 1.142–1.430], $p = .0002$), but again belonging was not

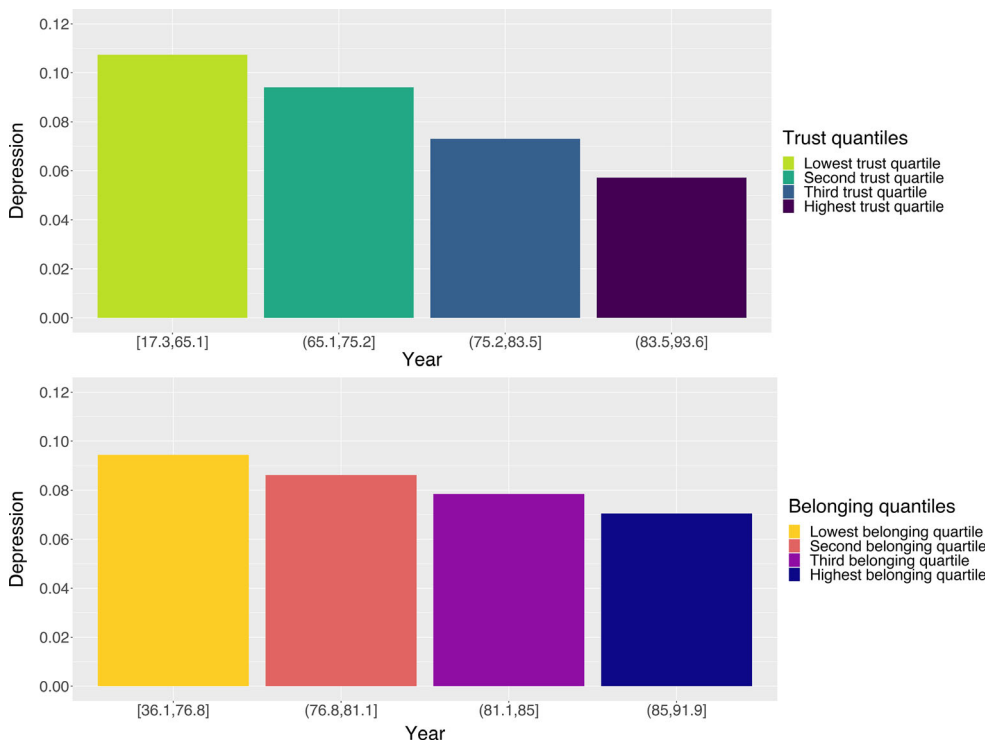


Figure 3. Rates of reported treatment for depression, broken down by ecological social capital quartile of the respondents' middle super output area of residence. Four bars showing a dose–response decrease in depression rates from low to high ecological social capital neighbourhoods, separately for generalized trust and belonging. The relationship is stronger for trust than for belonging.

protective ($OR = 0.934$ [$CI_{95\%}: 0.863–1.011$], $p = .0929$). The hypothesized interaction, again, was not significant ($OR = 1.008$ [$CI_{95\%}: 0.905–1.122$], $p = .8880$).

Age and sex

Results for age and sex were very similar across models. Women had a much higher rate of treatment for depression than men ($ORs > 5$). Rates of treatment for depression increased with age before peaking at around the age of 50 and declining again. Both of these effects were very large in comparison with those of the financial crisis.

Control analyses

Ecological social capital was the exposure of interest, but it was confounded with economic capital, given the high correlation between the MRP estimates and low pay rates (especially trust). Thus, the models were refitted including individual-level measures of National Statistics Socio-Economic Classification (NS-SEC), a classification of occupation type used in UK official statistics. The eight-level version of NS-SEC was used, with the highest level used as the reference category and fixed effects of each other level.

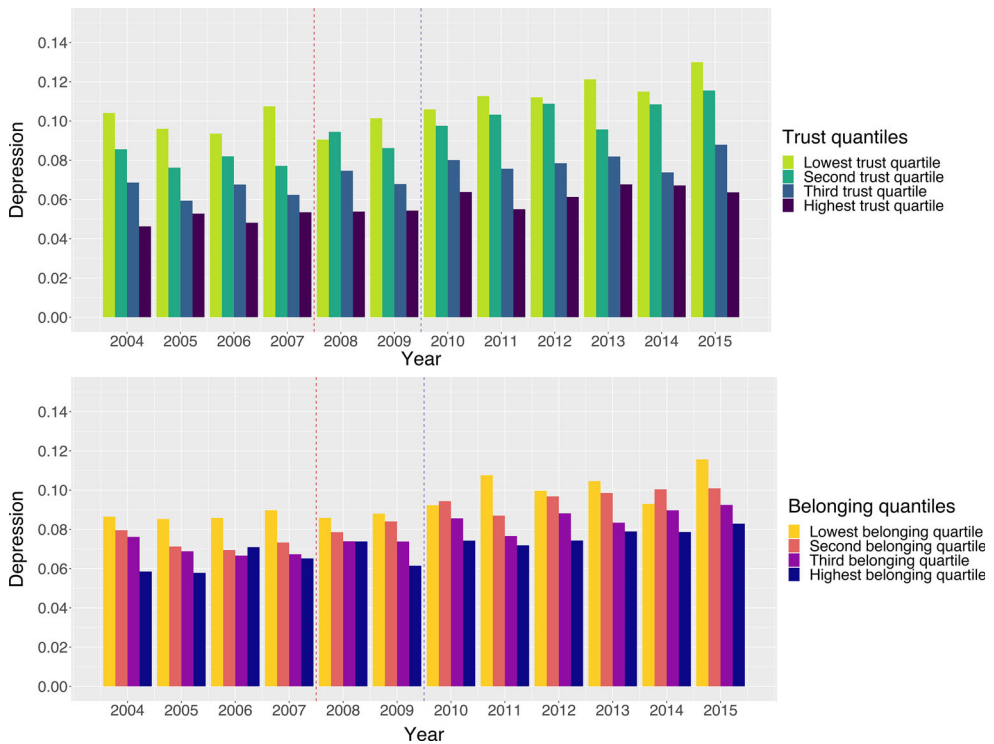


Figure 4. Rates of reported treatment for depression, broken down by ecological social capital quartile of the respondents' middle super output area of residence and by year. Red line indicates division of data into pre- and post-financial crisis epochs, and blue line indicates division of data into pre- and post-austerity epochs. Bars showing depression prevalence for each social capital quartile for each year, separately for generalized trust and belonging. There is a clear gradient from high to low trust, and a similar but less clear gradient for belonging. There is an overall increase across time, but no clear difference in trajectory by quartile for either variable.

Results from these models can be seen in Table 1 in the lower columns. Odds ratios are very similar to those seen in the analyses without NS-SEC: The effect sizes for trust are slightly, but not significantly, attenuated, while those for time point are slightly, but not significantly, larger. The terms for the different NS-SEC levels were all significant, with all showing a greater risk of depression than the top group and a general social gradient in depression, with the exception of group 4 (small employers and own-account workers) whose risk was similar to that of group 2.

Departures from preregistration

Because of some issues with model convergence, the `glmmTMB` function from the R package of the same name was used, rather than `lme4`. Models fitted using `lme4` with the number of adaptive Gauss–Hermite quadrature points set to zero yielded similar results, albeit with a significant protective term of belonging.

In the preregistration, household and MSOA were included as 'crossed' random effects, but they were modelled as nested random effects, as this seemed more

Table 1. Odds ratios with 95% confidence intervals for parameters of all models. Reference group for age was 16–19, reference group for sex was male, and reference group for NS-SEC was higher managerial and professional occupations

	Trust and crisis model			Trust and austerity model			Belong and crisis model			Belong and austerity model		
	OR		OR 95% CI		OR		OR		OR 95% CI		OR	
	OR	OR 95% CI	OR	OR 95% CI	OR	OR 95% CI	OR	OR 95% CI	OR	OR 95% CI	OR	OR 95% CI
Main analysis												
Ecological social capital	0.775	0.706–0.852	0.789	0.731–0.853	0.922	0.838–1.016	0.934	0.863–1.011				
Time point	1.271	1.123–1.438	1.28	1.142–1.435	1.265	1.12–1.429	1.278	1.142–1.43				
Sex: Female	5.664	5.222–6.143	5.663	5.221–6.142	5.682	5.238–6.164	5.681	5.237–6.163				
Age: 20–24	12.679	9.505–16.913	12.667	9.496–16.897	12.899	9.664–17.217	12.888	9.656–17.202				
Age: 25–29	25.325	18.706–34.288	25.301	18.688–34.254	26.092	19.259–35.35	26.07	19.243–35.318				
Age: 30–34	44.944	33.441–60.403	44.817	33.348–60.23	46.15	34.327–62.044	46.029	34.239–61.878				
Age: 35–39	51.89	39.107–68.851	51.939	39.145–68.916	52.618	39.644–69.837	52.68	39.692–69.92				
Age: 40–44	56.513	43.163–73.991	56.509	43.161–73.984	56.86	43.417–74.464	56.86	43.419–74.463				
Age: 45–49	74.817	57.199–97.862	74.771	57.165–97.799	74.867	57.226–97.946	74.815	57.187–97.875				
Age: 50–54	74.951	57.001–98.553	74.78	56.874–98.324	74.68	56.786–98.213	74.508	56.658–97.983				
Age: 55–59	68.249	51.452–90.529	68.2	51.417–90.461	67.58	50.942–89.653	67.532	50.907–89.586				
Age: 60–64	68.753	51.5–91.786	68.783	51.524–91.824	68.117	51.015–90.951	68.139	51.033–90.978				
Age: 65–69	39.794	29.14–54.344	39.673	29.053–54.174	39.365	28.816–53.774	39.229	28.719–53.585				
Age: 70–74	39.961	28.74–55.565	39.907	28.701–55.489	39.634	28.493–55.13	39.572	28.45–55.043				
Age: 75+	28.754	21.186–39.025	28.705	21.151–38.956	28.497	20.988–38.691	28.446	20.952–38.62				
Ecological social capital × Time point	1.033	0.922–1.157	1.008	0.908–1.12	1.025	0.913–1.151	1.008	0.905–1.122				
Analysis including NS-SEC												
Ecological social capital	0.824	0.747–0.908	0.84	0.775–0.909	0.939	0.848–1.039	0.951	0.875–1.034				
Time point	1.312	1.158–1.487	1.316	1.173–1.477	1.31	1.158–1.482	1.317	1.176–1.476				
Sex: Female	5.503	5.068–5.975	5.502	5.067–5.974	5.51	5.075–5.984	5.509	5.073–5.982				
Age: 20–24	14.73	10.88–19.942	14.717	10.871–19.924	14.87	10.98–20.138	14.856	10.97–20.118				
Age: 25–29	27.108	19.776–37.16	27.08	19.756–37.12	27.594	20.122–37.842	27.57	20.105–37.807				
Age: 30–34	51.54	37.904–70.08	51.357	37.772–69.827	52.477	38.585–71.369	52.289	38.45–71.11				
Age: 35–39	57.098	42.539–76.639	57.155	42.582–76.714	57.666	42.954–77.417	57.731	43.003–77.503				

Continued

Table 1. (Continued)

	Trust and crisis model			Trust and austerity model			Belong and crisis model			Belong and austerity model		
	OR	OR 95% CI		OR	OR 95% CI		OR	OR 95% CI		OR	OR 95% CI	
Age: 40–44	62.982	47.548–83.426		62.982	47.55–83.424		63.294	47.775–83.855		63.299	47.78–83.857	
Age: 45–49	82.458	62.295–109.148		82.408	62.259–109.077		82.589	62.384–109.336		82.526	62.339–109.249	
Age: 50–54	83.064	62.442–110.497		82.808	62.253–110.15		82.875	62.292–110.26		82.614	62.1–109.906	
Age: 55–59	76.32	56.902–102.366		76.269	56.866–102.293		75.804	56.512–101.681		75.75	56.474–101.604	
Age: 60–64	75.303	55.802–101.621		75.339	55.829–101.666		74.787	55.414–100.932		74.81	55.433–100.96	
Age: 65–69	43.638	31.673–60.123		43.489	31.567–59.914		43.206	31.355–59.536		43.043	31.239–59.307	
Age: 70–74	43.032	30.7–60.318		42.961	30.65–60.216		42.654	30.426–59.796		42.57	30.367–59.676	
Age: 75+	27.11	19.768–37.179		27.061	19.734–37.109		26.686	19.455–36.606		26.636	19.42–36.533	
Lower managerial and professional occupations	1.423	1.11–1.825		1.424	1.111–1.825		1.455	1.134–1.865		1.455	1.135–1.866	
Intermediate occupations	1.994	1.489–2.672		1.996	1.49–2.675		2.102	1.569–2.815		2.105	1.572–2.819	
Small employers and own-account workers	1.53	1.156–2.025		1.534	1.159–2.03		1.522	1.15–2.016		1.526	1.153–2.021	
Lower supervisory and technical occupations	2.013	1.546–2.623		2.016	1.548–2.626		2.129	1.635–2.772		2.132	1.637–2.775	
Semi-routine occupations	2.917	2.27–3.749		2.918	2.27–3.751		3.132	2.439–4.021		3.134	2.441–4.025	
Routine occupations	3.387	2.62–4.378		3.395	2.626–4.388		3.671	2.843–4.74		3.68	2.85–4.752	
Never worked and long-term unemployed	6.742	4.822–9.426		6.735	4.817–9.416		7.272	5.209–10.151		7.267	5.206–10.145	
Ecological social capital × Time point	1.038	0.924–1.167		1.013	0.909–1.128		1.034	0.915–1.168		1.019	0.91–1.141	

appropriate for the structure of the data (each household is only present in one MSOA). Models including a random slope of time point by MSOA failed to converge, so just the random intercepts were fitted.

Although it was not preregistered, I explored the possibility of fitting a full interrupted time series model (Bernal, Cummins, & Gasparrini, 2016) to the data, including terms for the crisis, year, and their interaction, as well as interactions of these terms with ecological social capital. Such models make clearer distinctions between abrupt changes in the outcome following the intervention, changes in growth rate following the interaction, and a trend in the outcome not related to the intervention. However, the models had multicollinearity estimates of over 10 for all terms, including, in one case, a variance inflation factor of 128,341,830,480.18! As such, the models did not seem useful as they clearly could not distinguish between terms, and so are not reported in detail here.

Discussion

Pre-crisis ecological generalized trust was a protective factor against depression across the study period, but did not buffer against the rise in depression rates seen during the period. Ecological sense of belonging was not protective, either in general or as a buffer against the post-crisis increase in depression rates.

Considering the high correlation between ecological social capital estimates and area measures of deprivation, it is particularly surprising that ecological social capital did not moderate the increase in depression rates post-crisis. This suggests that it was not necessarily the most deprived areas that saw the largest increase in depression following the crisis, and, more strikingly, during the period of austerity. This sits at odds with much of the literature on the health consequences of European austerity (Stuckler, Reeves, Loopstra, Karanikolos, & McKee, 2017).

One possibility is that ecological risk factors were less important in determining vulnerability to financial distress than individual factors – a number of studies have found that individual demographic (Barr *et al.*, 2015) and socio-economic (Thomson & Katikireddi, 2018) factors acted as moderators of risk, and potentially ecological factors are less relevant in an economic crisis than in natural disasters. That said, area rates of housing foreclosure did predict declines in the mental health of residents in an American study (Houle, 2014), so ecological risk/protective factors have been observed in a similar context.

Another possibility is that pre-crisis ecological social capital measured in this way is a poor predictor of the degree of actual social solidarity shown during a crisis, even if it is predictive cross-sectionally. A third possibility is that the somewhat crude pre–post comparison did not capture time-varying effects of social capital. That said, such a pattern is not obvious in the plots of the data. A final, provocative, possible conclusion is that the aftermath of the financial crisis may have seen less widening of geographical and social inequalities in mental health than is generally believed to have taken place. Evaluating this conclusion requires further examination of data from other contexts.

It is worth noting that the lack of a protective status of belonging sits in contrast to previous work in Wales, which found that it was a protective factor against psychiatric admission (Saville, 2019). This may be due to changes in ecological social capital on the ground; Saville (2019) used data from 2016/17, more than a decade later than the present study. Given that the financial crisis itself likely had an effect on social capital (Lindström &

Giordano, 2016), it is plausible that the geography of ecological social capital may be somewhat different in the two studies. Alternatively, it could be because different variables were used for modelling ecological social capital to the previous paper. Due to the availability of different variables in the 2001 and 2011 censuses, it was not possible to use the same variables as were used in the previous paper, so the construct measured is likely somewhat different. Specifically, sense of belonging was less correlated with measures of material deprivation in the present study.

This raises the possibility that ecological social capital is not protective for mental health in its own right, but instead because it acts as a marker for lower material deprivation. Social capital and economic capital are of course conceptually and empirically intertwined (Stafford *et al.*, 2003), so attempting to disentangle their effects would not be straightforward, but these results could be read as supportive of a material view of mental health risk factors, rather than a social capital view. That said, it is important to remember that ecological generalized trust remained protective after adjusting for individual socio-economic status.

These results should also be considered in the light of those of Economou *et al.* (2014), Frank *et al.* (2014), and Lindström and Giordano (2016), who also looked at social capital's protective status in the context of the financial crisis. Economou *et al.* found that trust was not protective in those who were experiencing financial distress. The study was different in several important respects to this one – trust was measured on the individual, rather than the area, level; data were captured cross-sectionally, rather than compared to a pre-crisis baseline, etc. – but the bottom line of the two sets of results – that social capital cannot buffer against the consequences of a major economic crisis – is consistent. Frank *et al.*, in contrast to the present study, found evidence of moderation of risk of depression by social capital. However, social capital was measured on the individual level and contemporaneously with depression, in contrast to the present study which looked at the protective status of pre-crisis social capital on the ecological level. Comparisons with Lindström and Giordano (2016) highlight a few issues with the present study. The financial crisis probably affected trust itself, and the pre-crisis measure of trust may not have been predictive of where this loss of trust was greatest.

Strengths and limitations

The study had important strengths. Firstly both the MRP estimates and the analysis of depression rates themselves were based on very large samples, collected using random probability sampling, representing *c.* 1.9% and *c.* 7.8% of the population of Wales respectively. This was an advantage in examining this question in Wales, a small country where such a sample represents a relatively large proportion of the population. This dense sampling means that genuine local variance can be reflected in the MRP estimates, rather than relying on the broader demographic and area-level variables included in the model.

The use of MRP to create small area estimates of ecological social capital is a strength of the study. Most studies in the ecological social capital literature simply aggregate responses by area, which leads to unacceptably high margins of error (see Saville, 2019). MRP estimates have been shown to have greater predictive validity for psychiatric admission rates than the simple aggregation approach (Saville, 2019).

The study also had important limitations. It was not possible to use a full interrupted time series model due to multicollinearity issues. Thus, the time point term in the models combined any immediate effect of the crisis with wider trends in depression treatment, as

well as longer term effects of the crisis. Plausibly ecological social capital buffered against some of these phenomena but not others, but in aggregate, this could not be detected. Furthermore, although this study is consistent with the financial crisis being associated with an increase in depression, the models were not optimized to measure this putative effect, so caution should be taken in interpreting this study as supporting other studies' findings (Barr *et al.*, 2015; Chang, Stuckler, Yip, & Gunnell, 2013) that the crisis led to an increase in mental health problems.

It is also important to acknowledge that the link between ecological social capital and depression rates is correlational. It is possible that a third variable is the causal variable behind both, or indeed that high depression rates have an adverse effect on ecological social capital. When mapping the MRP estimates, trust in particular, the areas with low ecological social capital – for example, the south Wales valleys, coastal Denbighshire – were also areas of broader economic disadvantage. Analyses were rerun controlling for individual-level socio-economic status and trust remained protective, but it is possible that residual confounding or contextual effects of economic disadvantage account for some or all of the association of depression with ecological trust. As mentioned previously, the lack of protective status of sense of belonging here, in contrast to previous work, may be explained by the weaker relationship with material poverty in the measures used in the present study.

More broadly, it was not possible to model trust and belonging using the same variables as used previously (Saville, 2019) due to the 2001 and 2011 censuses using different variables and slightly different question wording in the two questionnaires used. Thus, some care should be taken when comparing results across the two studies.

The question used to measure depression referred to treated depression, and as such, is likely to be an underestimate of the true prevalence of depression. Furthermore, people's propensity to seek treatment might be correlated with social capital so that the extent to which it is an underestimate varies according to ecological social capital, confounding the analysis. Changes to provision of services, for better or for worse, during the study period are another possible confound. There may also be a lag in the incidence of treated depression that makes it hard to identify whether the increase is due to the primary effects of the financial crisis or the policy response. That all said, the measure of trust did correlate negatively with the depression measure, suggesting that these issues did not completely invalidate the dependent variable.

Conclusions

Ecological generalized trust appears to have been a protective factor against depression between 2003 and 2015, but did not buffer against the increase in depression following the global financial crisis. Ecological sense of belonging, in contrast to previous research, was not protective. The results suggest that although ecological social capital may well be a valuable community resource, there is no evidence that it can protect residents from wider economic shocks. They are also at odds with a view of the aftermath of the financial crisis as a time of widening mental health inequalities.

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Conflicts of interest

All authors declare no conflict of interest.

Author contribution

Christopher W. N. Saville (Conceptualization; Formal analysis; Methodology; Resources; Software; Visualization; Writing – original draft; Writing – review & editing).

Data availability statement

All survey data can be found via the UK Data Service (<https://www.ukdataservice.ac.uk/>, specific DOIs below), except data of place of residence of survey respondents, which must be requested from the Welsh Government's Surveys Team (Surveys@gov.wales). UK 2001 Census data can be found at <https://www.nomisweb.co.uk/>. Social capital estimates and the preregistered script can be found at <https://osf.io/7ebd8>. Specific DOIs: <http://doi.org/10.5255/UKDA-SN-6353-1>, <http://doi.org/10.5255/UKDA-SN-5692-1>, <http://doi.org/10.5255/UKDA-SN-5693-1>, <http://doi.org/10.5255/UKDA-SN-5750-1>, <http://doi.org/10.5255/UKDA-SN-6052-1>, <http://doi.org/10.5255/UKDA-SN-6372-1>, <http://doi.org/10.5255/UKDA-SN-6589-2>, <http://doi.org/10.5255/UKDA-SN-6895-1>, <http://doi.org/10.5255/UKDA-SN-7188-1>, <http://doi.org/10.5255/UKDA-SN-7459-1>, <http://doi.org/10.5255/UKDA-SN-7632-1>, <http://doi.org/10.5255/UKDA-SN-7841-1>, and <http://doi.org/10.5255/UKDA-SN-8090-1>

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